Tipping points in Greater Yellowstone forests with increasing wildfire activity

Abstract

Background/Question/Methods

A key unknown is whether forests will respond incrementally to increasing wildfire potential as climate warms, or exhibit tipping points, where small increases in fire activity result in sharp declines in forest resilience. We used an individual-based forest-landscape simulation model (iLand) to simulate five landscapes in Greater Yellowstone (Wyoming, USA). We explored forest responses to wildfire projections for three general circulation models and two relative concentration pathways, resulting in an array of different wildfire scenarios through the end of the century (600 simulations per landscape). Projected fire rotations—the number of years it takes to burn an area equal to each landscape—ranged from 10 to 300 years. We leveraged this range of variation to assess if the relationship between fire activity (fire rotation) and forest state (forest extent, stand structure, and carbon cools) is linear or exhibits thresholds, captured by a split-linear model.

Results/Conclusions

By the year 2100, simulated forest extent, tree density, basal area, and aboveground carbon pools all exhibited non-linear relationships with fire rotation. Compared to linear models, split-linear models had Akaike's information criteria scores that were lower for all response variables, suggesting non-linear models were more parsimonious. As fire rotation decreases, forests go through a series of tipping points, with stand density and basal declining first (if fire rotation falls below 80 years), then aboveground carbon storage (if fire rotation falls below 60 years), and finally, forested area (if fire rotation falls below 40 years). For example, as fire rotation decreases from 100 years to 40 years, forest extent declines slightly from ~100% to ~80%, but when fire rotation decreases from 40 years to 10 years, forest extent declines from ~80% to ~10%. The implication is that subalpine forests may be resilient to changing fire regimes until a threshold is passed, at which point forest resilience declines steeply. Simulations with lower greenhouse gas emissions (referred to as RCP 4.5) were consistently less likely to cross these key thresholds.

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